Assimilation of Satellite Precipitation and Soil Moisture Data into the WRF-Noah Model

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1. Motivation and Objectives

Motivation:

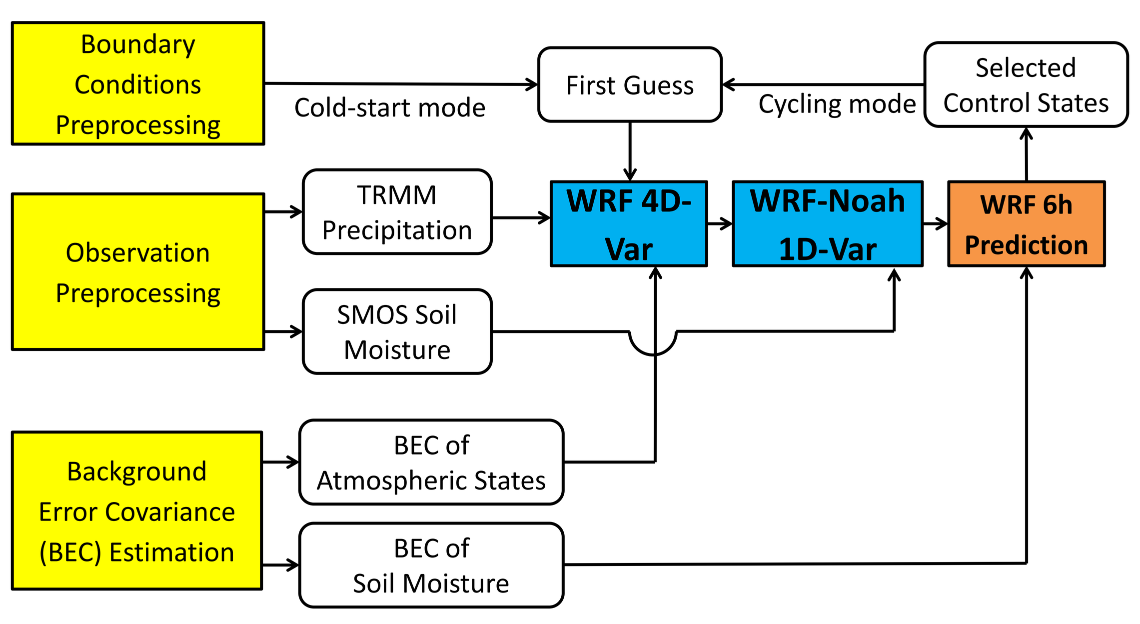
- To understand the relative impact of remotely-sensed precipitation and soil moisture (two of the most important variables in hydrologic cycles) in simulations of land-atmosphere interactions and hydrologic forecasts.

Objectives:

- Develop a joint data assimilation using the WRF-Noah model to assimilate satellite rainfall and soil moisture simultaneously.
- Quantify the relative impacts of satellite rainfall and soil moisture data assimilation on WRF-Noah rainfall and soil moisture prediction and hydrologic forecasts.

2. Modeling Framework and Experiment Design

EXPERIMENT DESIGN



Key Setting	
Background	NCEP FNL global analysis dataset at a 1x1 degree resolution every six hours
Background Error Covariance	Using the National Meteorological Center (NMC) method to estimate the background error covariance.
Experiment	• OL: open-loop forecasts without data assimilation • PrDA: assimilation of six-hour TMPA 3B42 precipitation • PrSMDA: assimilation of six-hour TMPA 3B42 precipitation + orbital SMOS soil moisture
Background Error Covariance	Using the National Meteorological Center (NMC) method to estimate the background error covariance.
Duration	1-28 July 2013

BACKGROUND ERROR

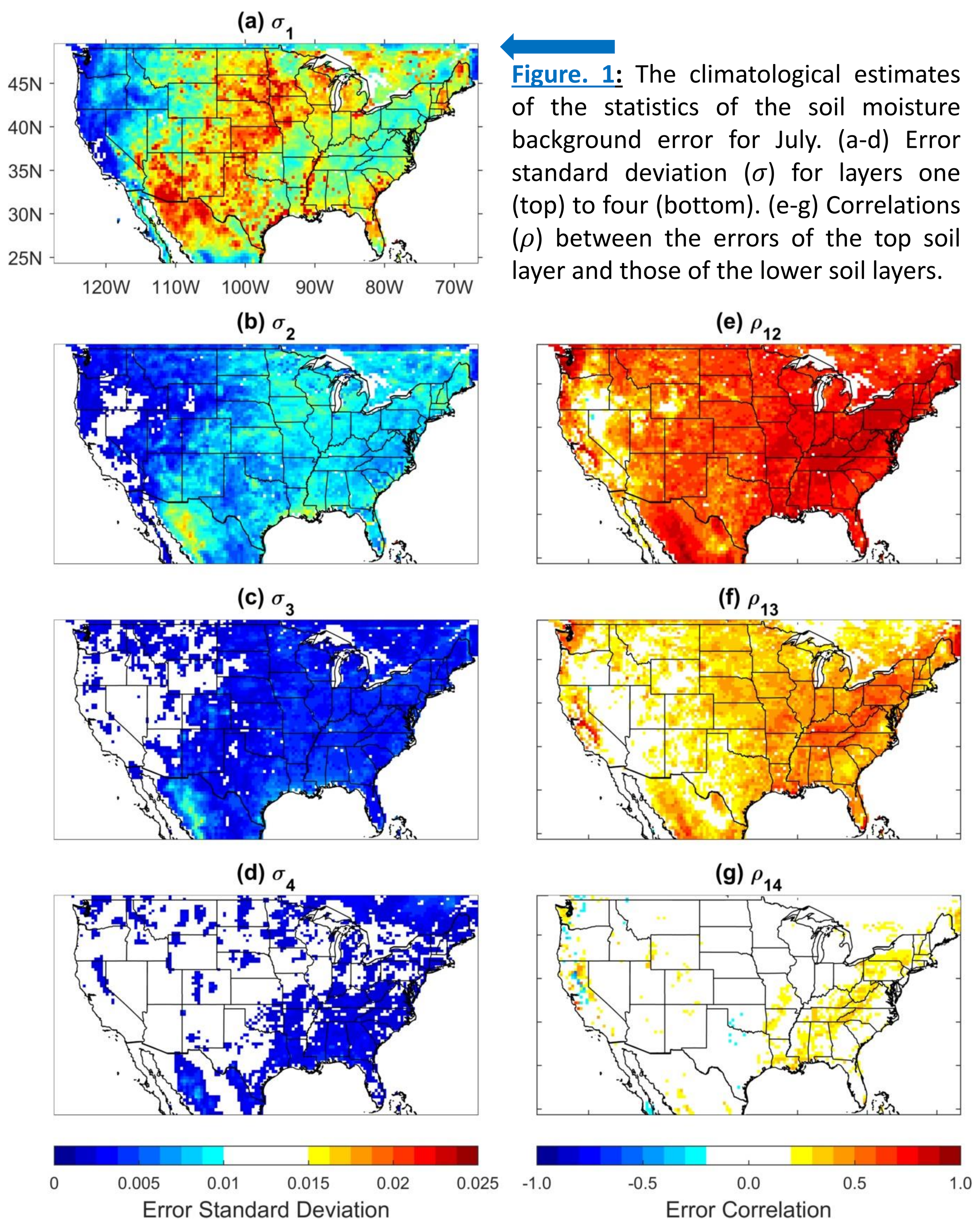


Figure. 1: The climatological estimates of the statistics of the soil moisture background error for July. (a-d) Error standard deviation (σ) for layers one (top) to four (bottom). (e-g) Correlations (ρ) between the errors of the top soil layer and those of the lower soil layers.

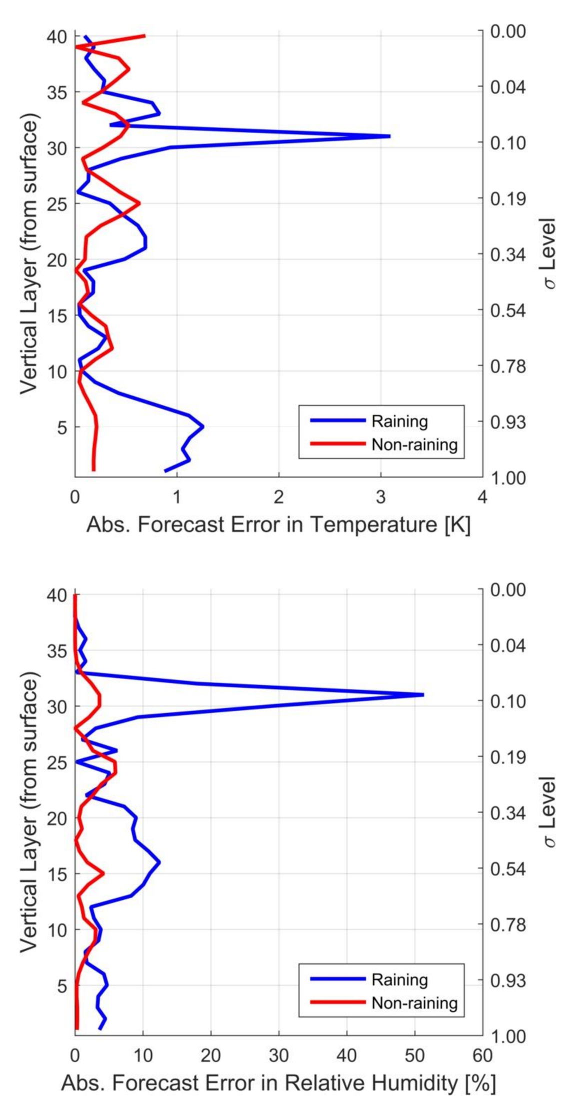


Figure. 2: Domain (areas covering the Kansas and Oklahoma states) averaged forecast errors of temperature and relative humidity during rainy and non-rainy events situations (i.e., 12h errors valid at 12 UTC 24 July and 00 UTC 05 July, 2013, respectively).

3. Overall Comparison of the Joint Data Assimilation Experiments

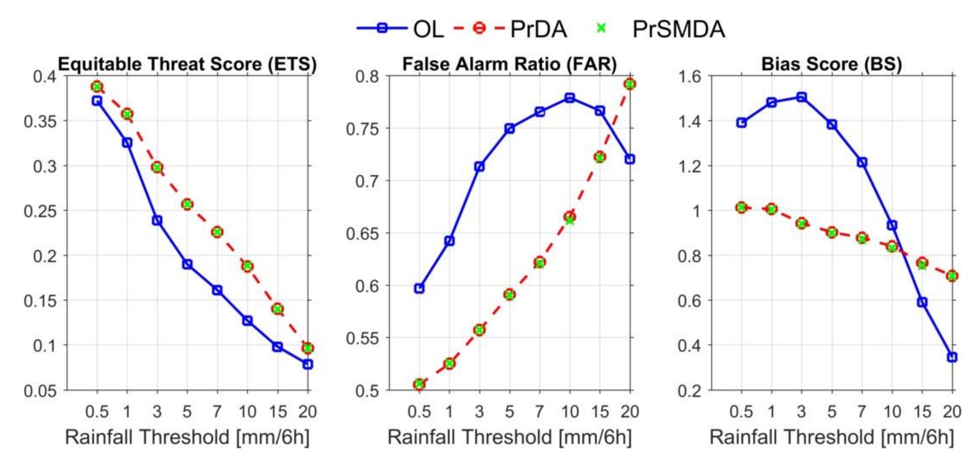


Figure 3. The score analysis obtained by comparing the six-hour WRF precipitation analyses against the NCEP Stage IV precipitation data at a resolution of 36 km.

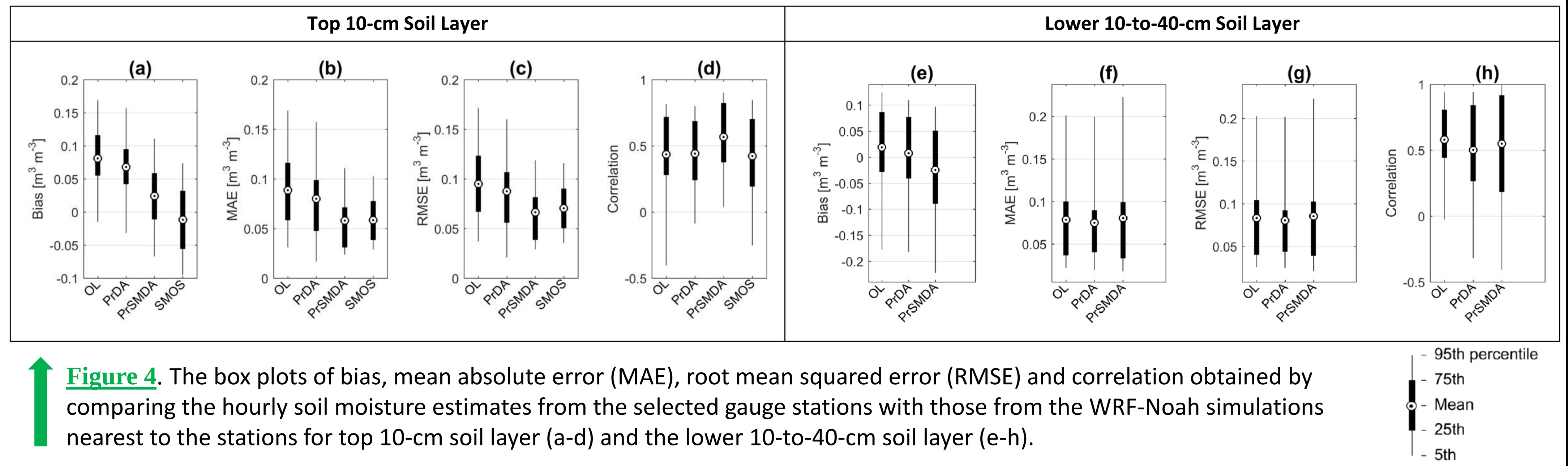
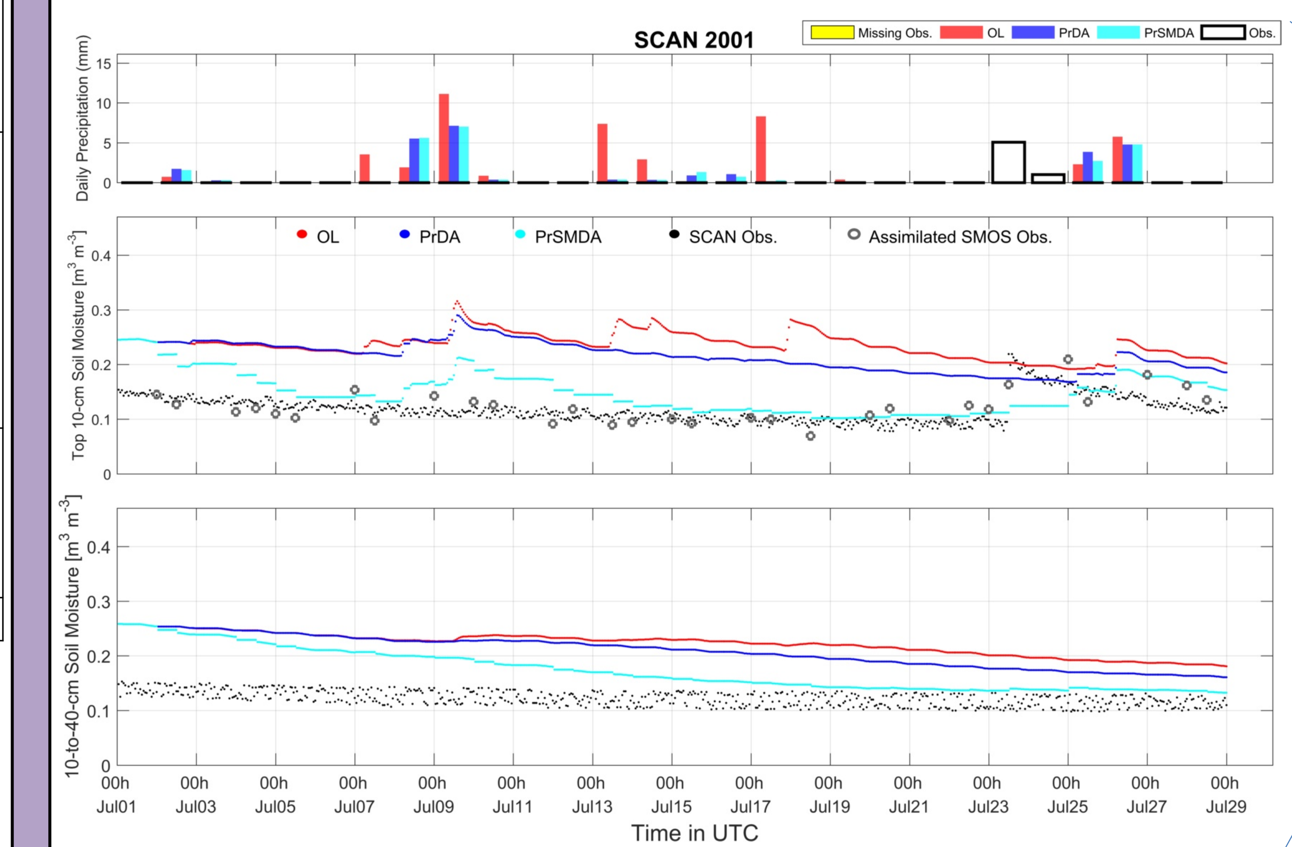
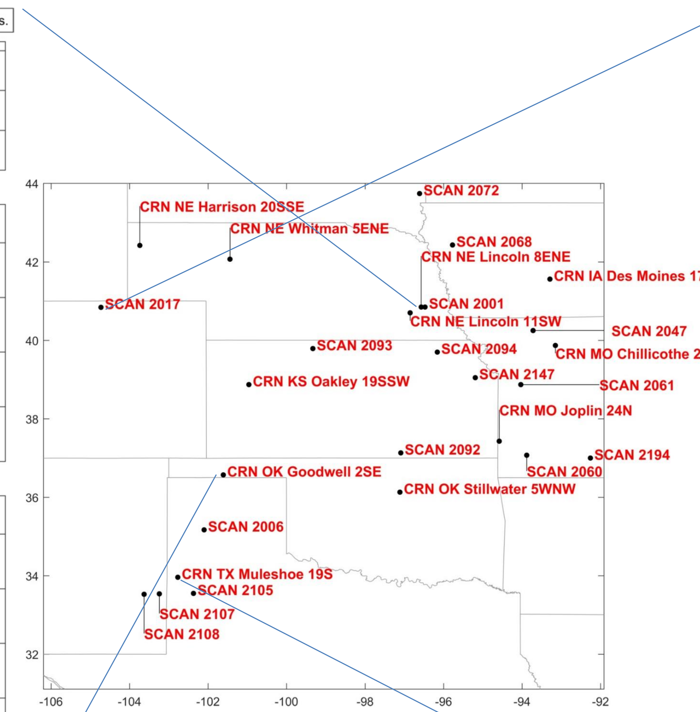
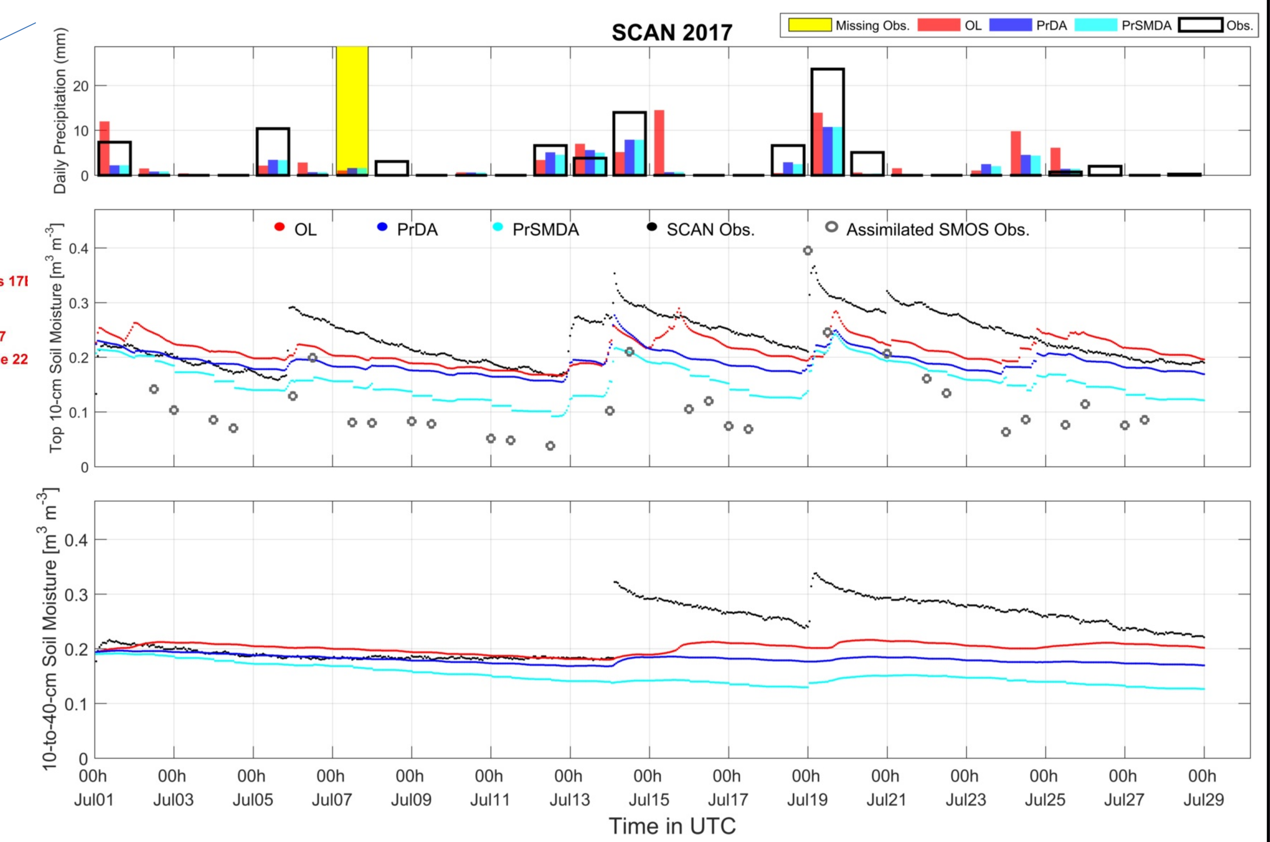


Figure 4. The box plots of bias, mean absolute error (MAE), root mean squared error (RMSE) and correlation obtained by comparing the hourly soil moisture estimates from the selected gauge stations with those from the WRF-Noah simulations nearest to the stations for top 10-cm soil layer (a-d) and the lower 10-to-40-cm soil layer (e-h).

4. Comparison of Selected Time Series







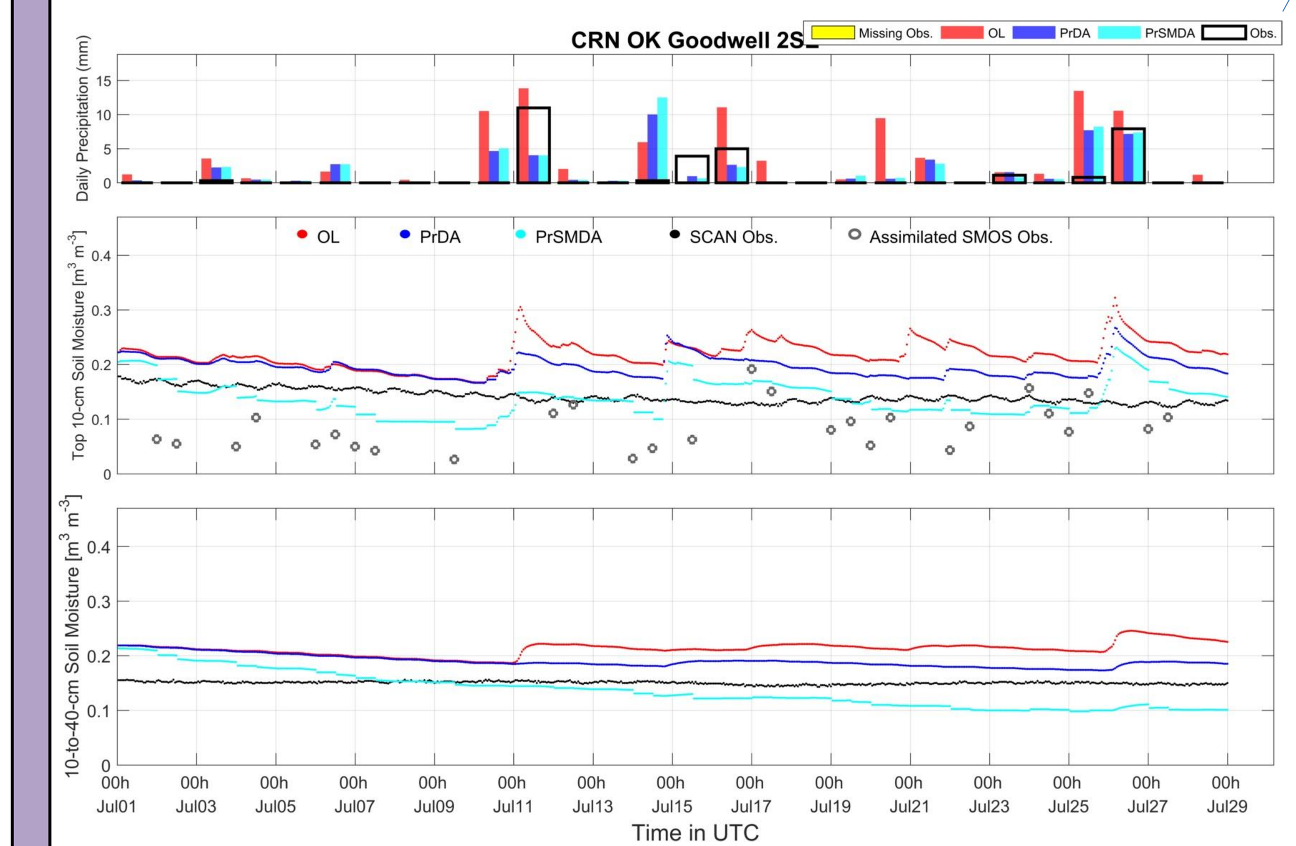
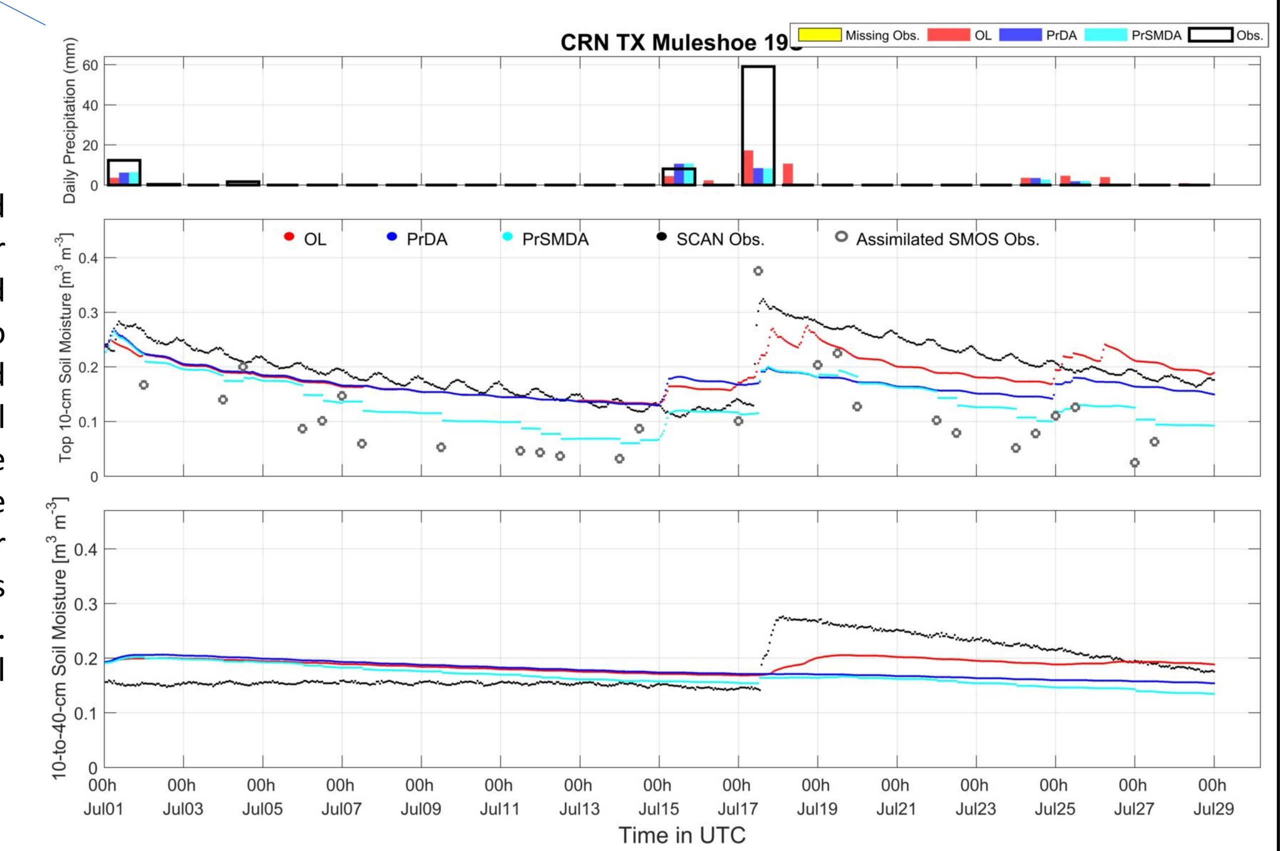


Figure 5-8. Daily precipitation (mm) and hourly soil moisture comparison for four selected stations. WRF simulations and SMOS data of 36 km resolution nearest to the selected gauge stations are compared with the reference data. The left panel shows two selected stations, in which the model soil moisture estimates from the PrSMDA experiment have a closer agreement with the SCAN/CRN observations than those from the open-loop experiment. The two selected stations of the right panel show the opposite.



5. Findings and On-going Work

Findings:

- The assimilation of TRMM 3B42 six-hour precipitation notably improves WRF precipitation analyses, while the simultaneous assimilation of SMOS soil moisture and TRMM precipitation does not provide additional significant benefits on precipitation analyses.
- Both assimilation of TRMM and SMOS data reduces errors of surface soil moisture simulations. TRMM data assimilation reduces the occurrence of falsely-produced open-loop precipitation, directly leading to more accurate soil moisture simulations. TRMM data assimilation results in the reduction of bias, MAE, and RMSE by 16%, 10%, and 8%, respectively in the top 10-cm layer, while adding SMOS data assimilation contributes additional 54%, 24%, and 22% reduction. SMOS data assimilation also increases the temporal variability of hourly soil moisture by 22% in terms of correlation.

On-going work:

- Assimilation of IMERG precipitation and SMAP soil moisture into domains of finer spatial resolutions (e.g., ~10 km).
- Assimilation of radiance observations from GPM constellation
- Bias characterization of remotely-sensed and model-based soil moisture estimation.

Acknowledgments

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